Applying Sustainable Development Goals to the Conservation of Winter Environments and Cold-adapted Species in a Warming World

Benjamin Zuckerberg[1], David Gudex-Cross[1], Spencer R. Keyser[1], Daniel Fink[2], Jonathan N. Pauli[1], Madeline Rubenstein[3], Volker C. Radeloff[1]

University of Wisconsin – Madison[1]

Cornell Lab of Ornithology[2]

National Climate Adaptation Science Center[3]

Project: 18-SLSCVC18-0001

Investigators: B. Zuckerberg, V. C. Radeloff, J. N. Pauli, M. Rubenstein, D. Fink

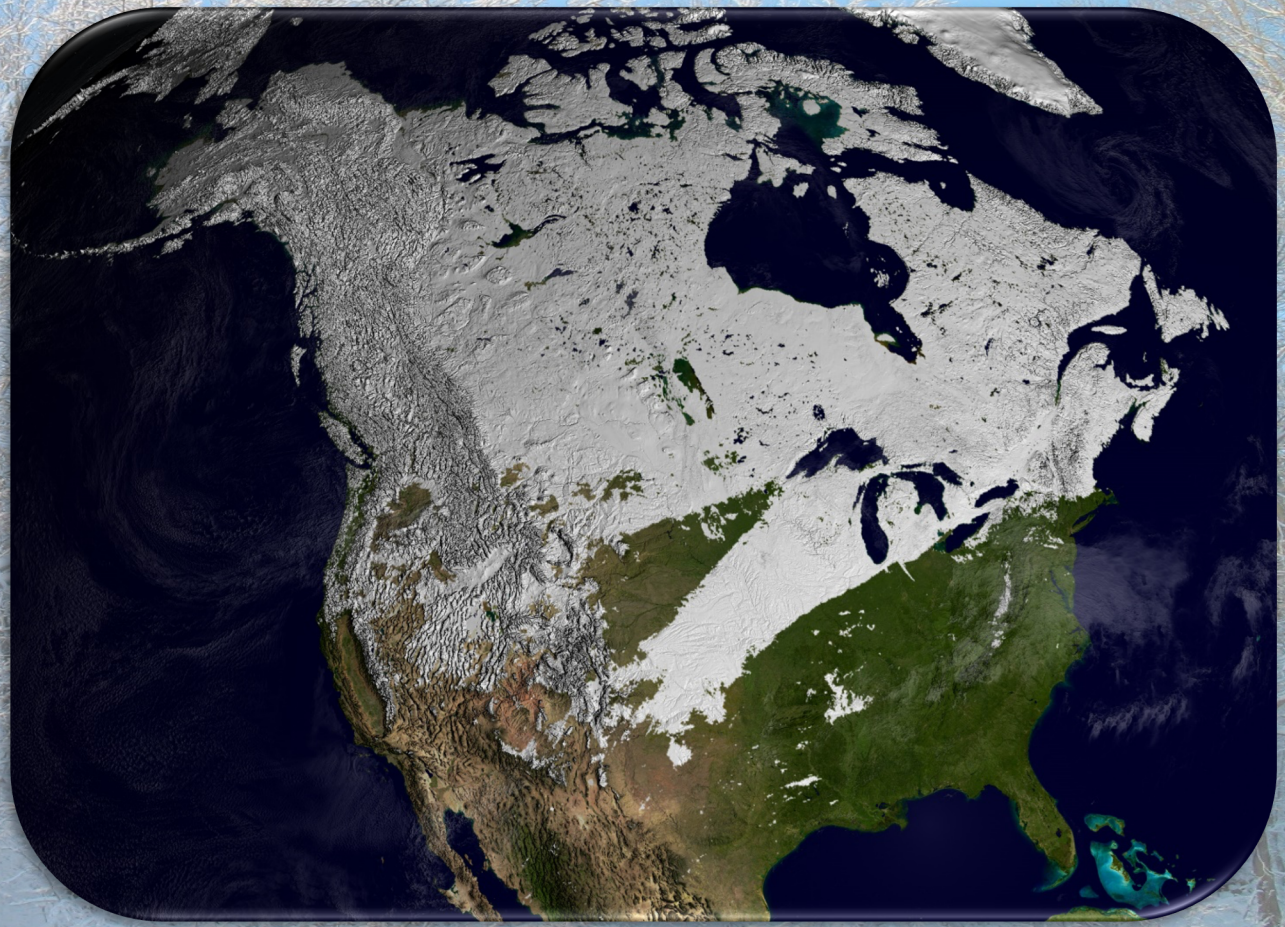
Winter: More than meets the eye

Pauli et al. 2013; Zuckerberg and Pauli 2018

Snow == Habitat

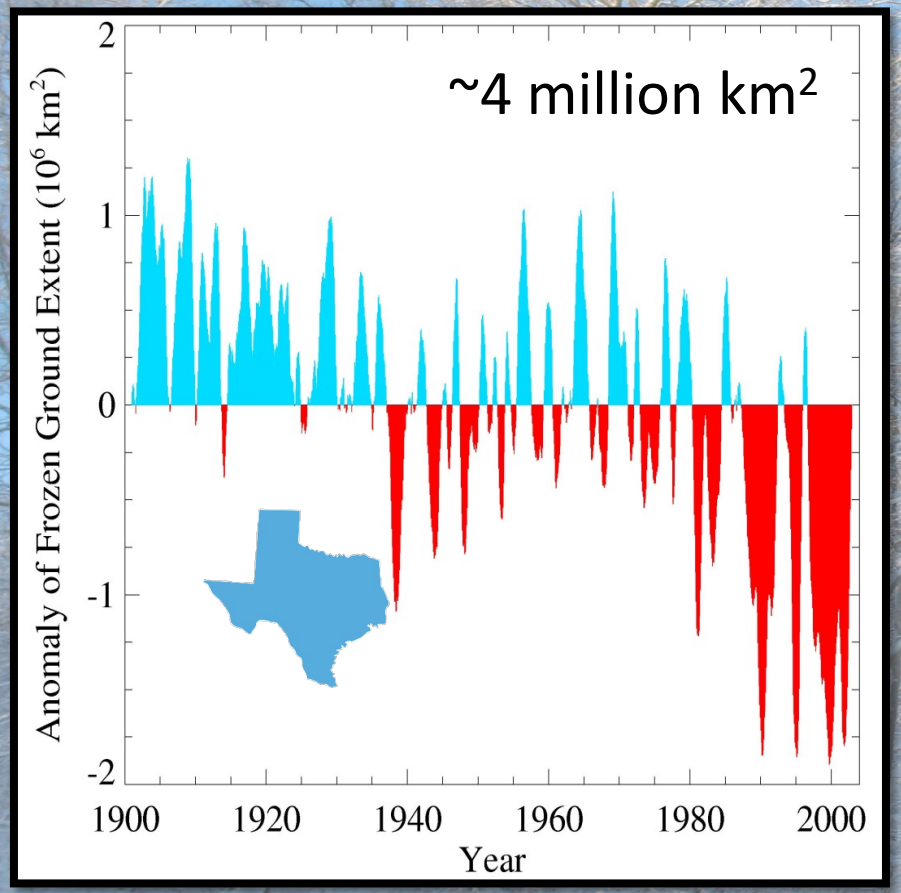
Extent
Duration
Variability
Subnivium

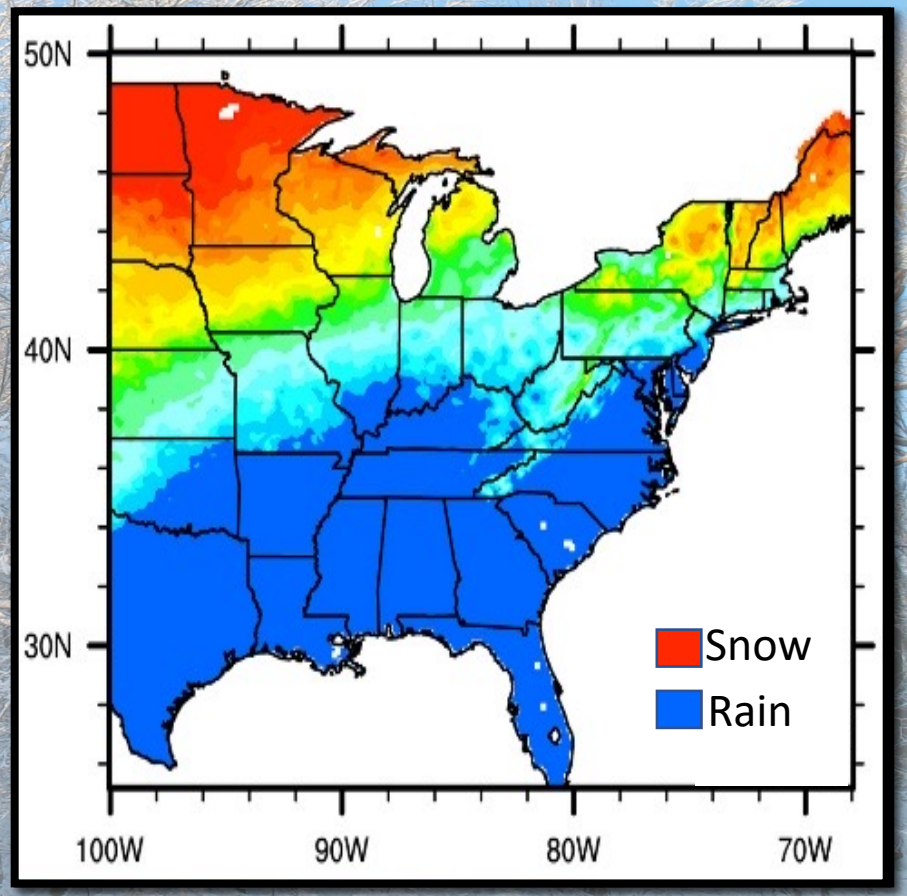
Physiology
Abundance
Interactions
Distribution



Slatyer et al. 2021

Snow in a warming world





Brown and Robinson 2011; Ning and Bradley 2015

Addressing UN Sustainable Development Goals

SDG 15 – ‘Life on Land’

Proportion of important sites for terrestrial biodiversity that are covered by protected areas (15.1.2)

Mapping winter biodiversity

Assessing protect areas coverage for important winter biodiversity

Project Objectives

Develop ecologically-relevant metrics to capture snow cover dynamics at regional and global scales using existing remotely sensed data

Integrate snow cover dynamics with large-scale, citizen science data to improve distribution modelling for winter vertebrate communities

Map winter biodiversity “hotspots” across multiple extents to assess and improve the conservation of winter biodiversity

Winter Habitat Indices

Snow – optical multispectral sensors

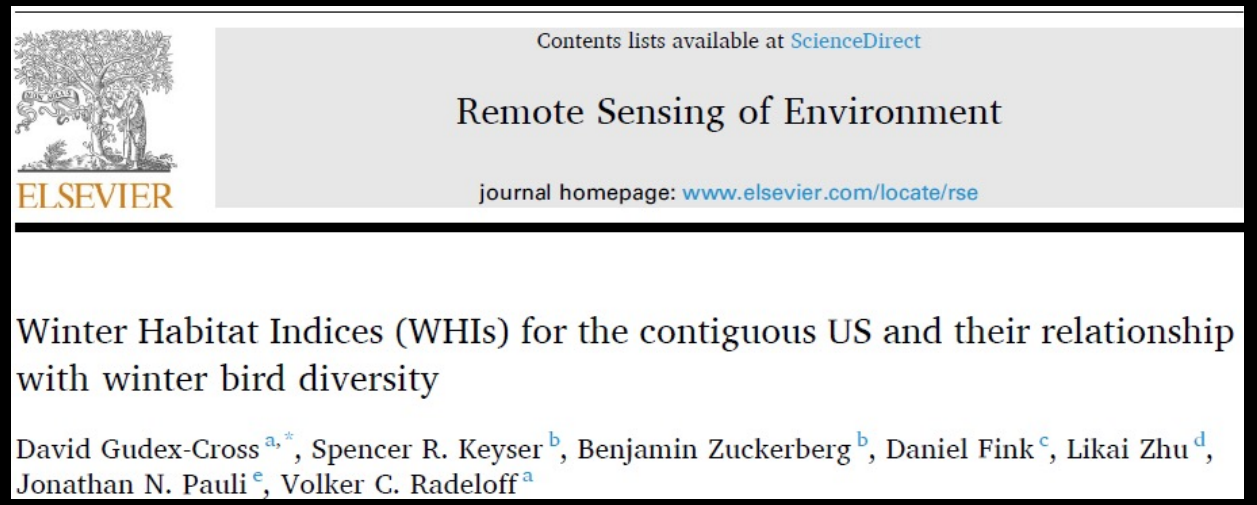
Satellite/Sensor	Spatial Resolution	Imaging Frequency	Data Record
MODIS*	500m	Daily	2000-On
Landsat (all sensors)	30m	16 days	1985-On
Landsat 8	30m	16 days	2013-On
Sentinel 2	10-30m	5 days	2017-On
Harmonized L8-S2	30m	2-3 days	2017-On

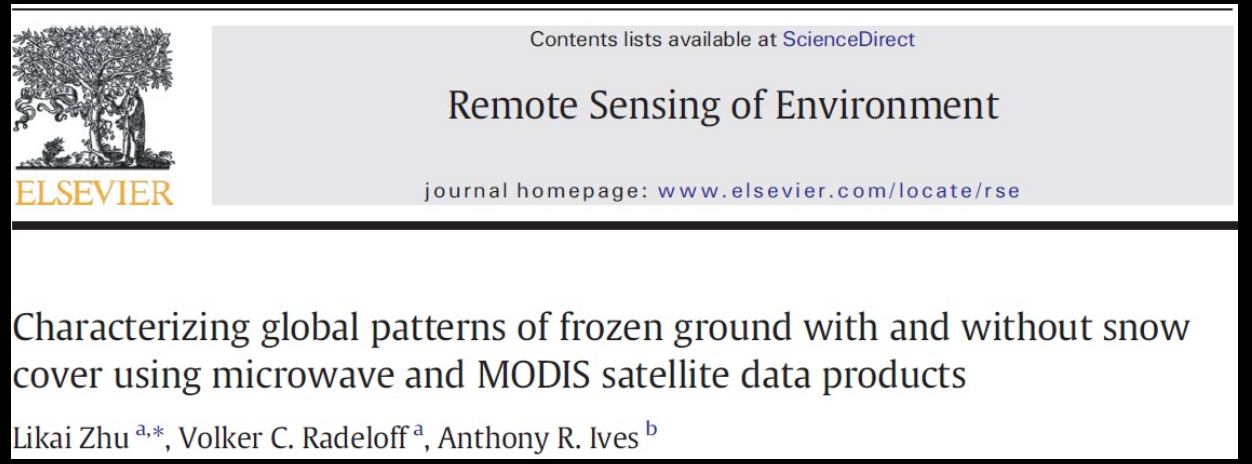
*Data from both MODIS sensors (Aqua & Terra) begin in 2002

Frozen ground – microwave sensors

Data Product	Spatial Resolution	Image Frequency	Data Record
MEaSUREs Freeze/Thaw	6-25km**	Daily	1979-2018*

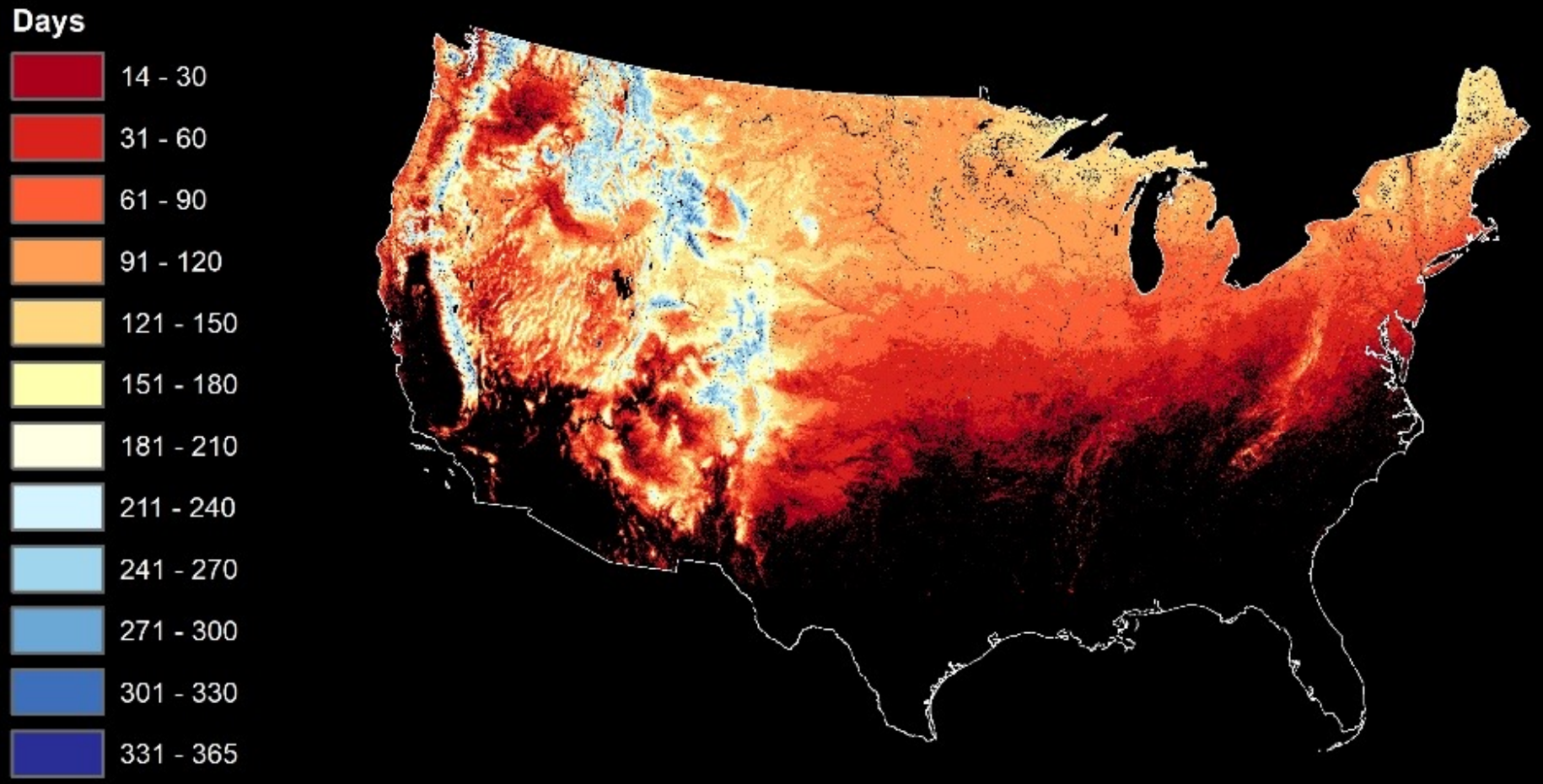
**6 km data only available for the Northern Hemi from 2002-2018





Winter Length

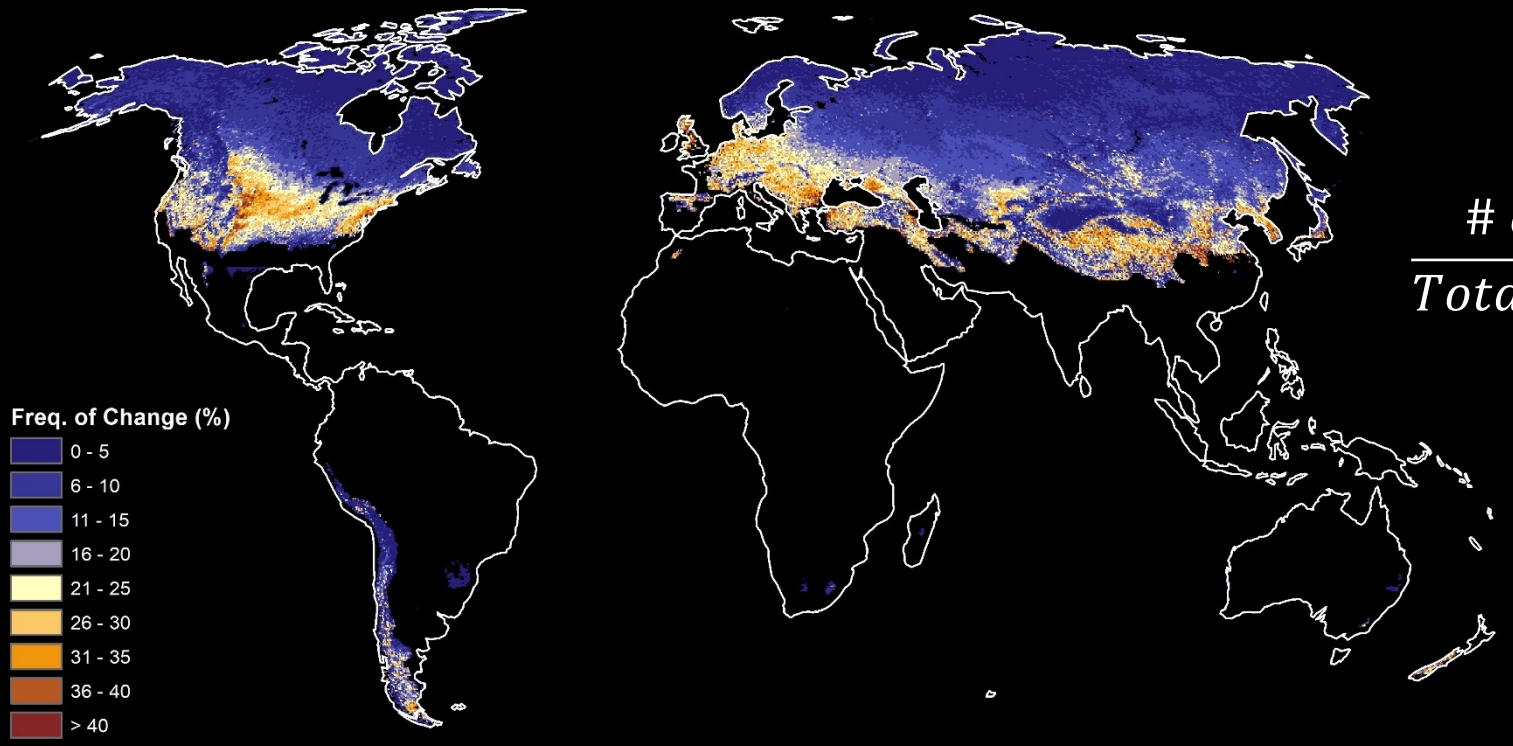
Snow season length *= # days between first & last snow*



Snow Cover Variability

Example Time-Series:

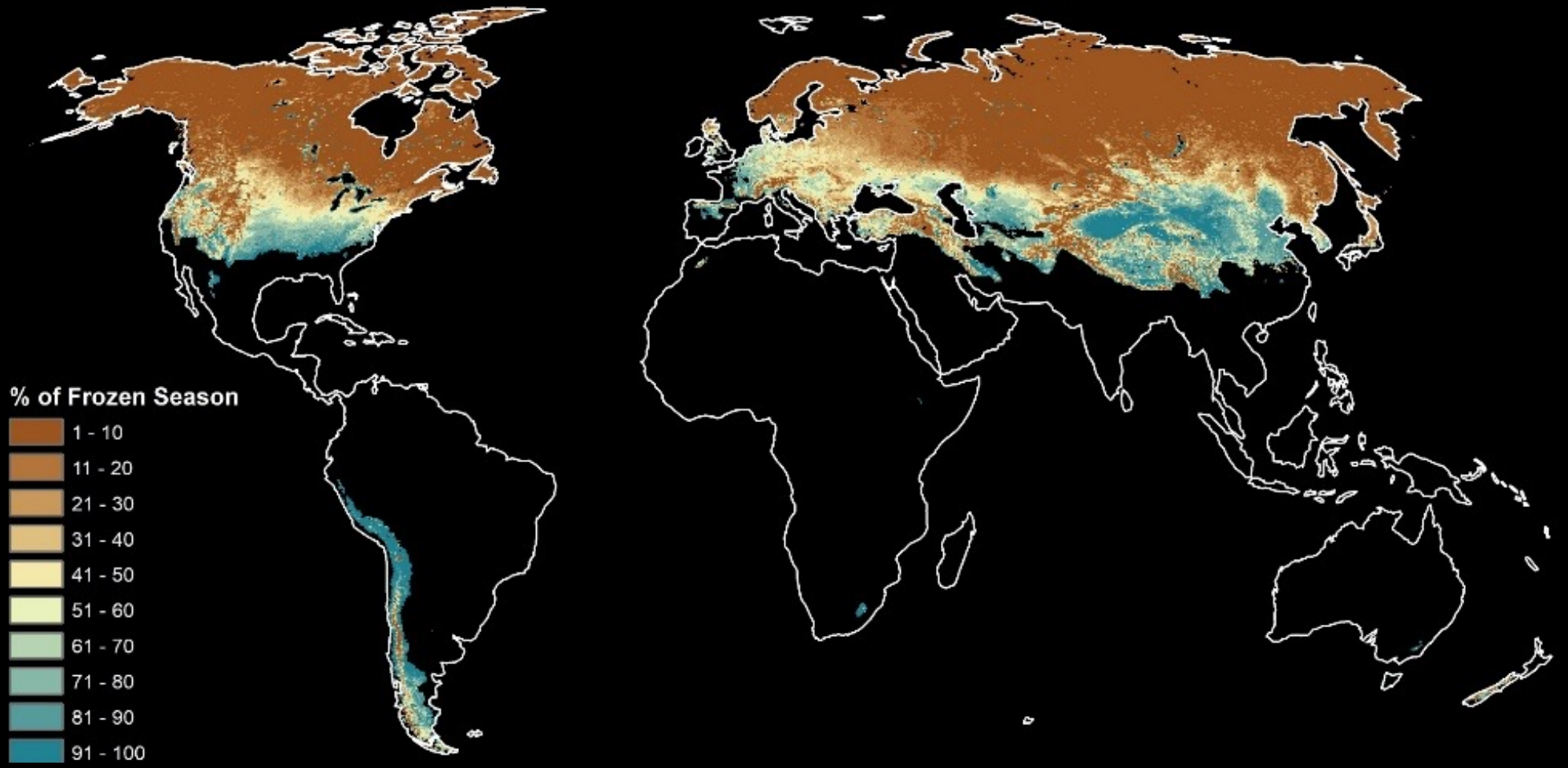
	no snow	no snow	snow	snow	snow	no snow	no snow	snow	snow	no snow	
State	0	0	1	1	1	0	0	1	1	0	= 10 total obs
Abs(Change)		0	1	0	0	1	0	1	0	1	= 4 change events
											SCV = 40%

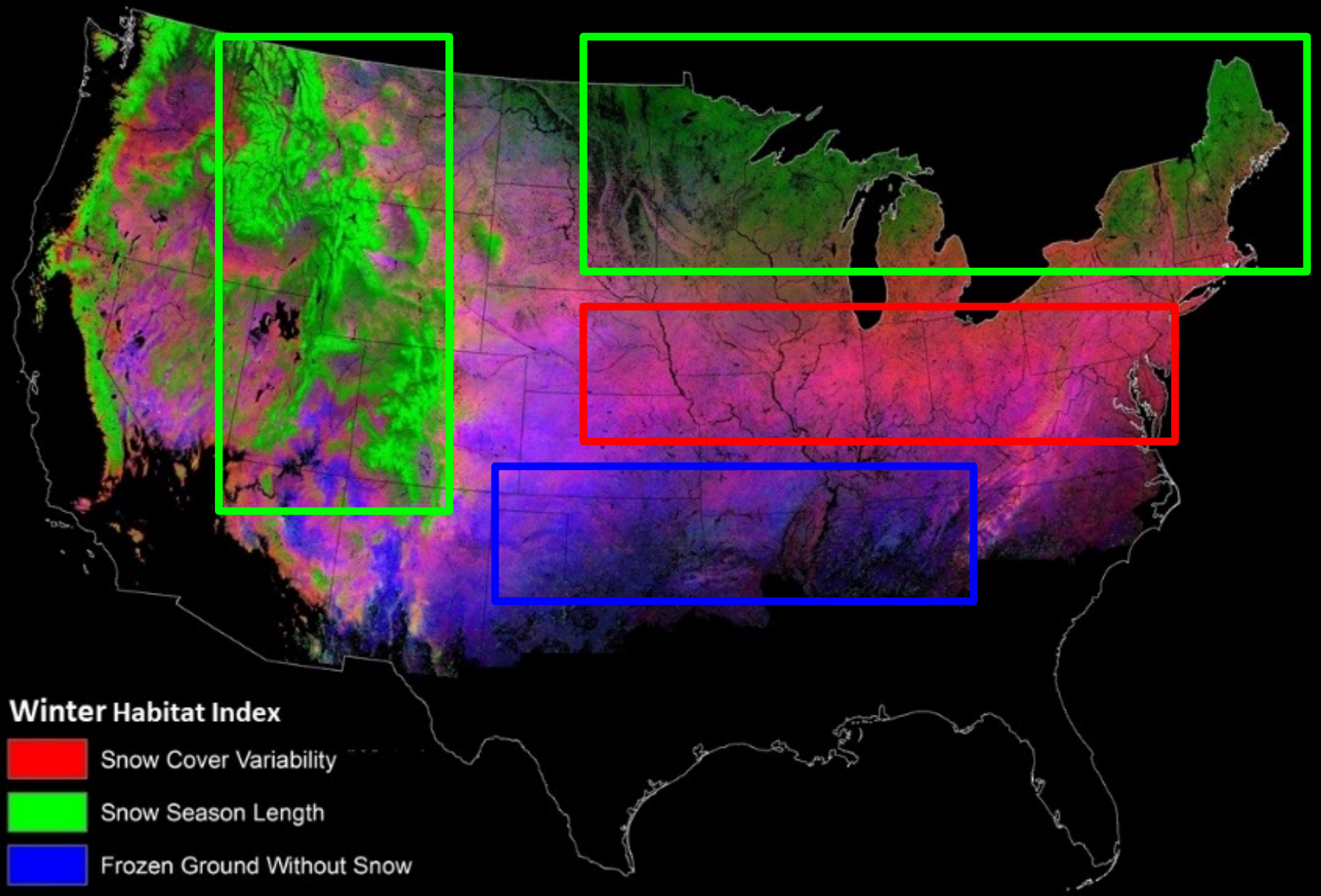


$$\frac{\#\ of\ Change\ Events}{Total\ \#\ of\ Observations}$$

Subnivium Conditions

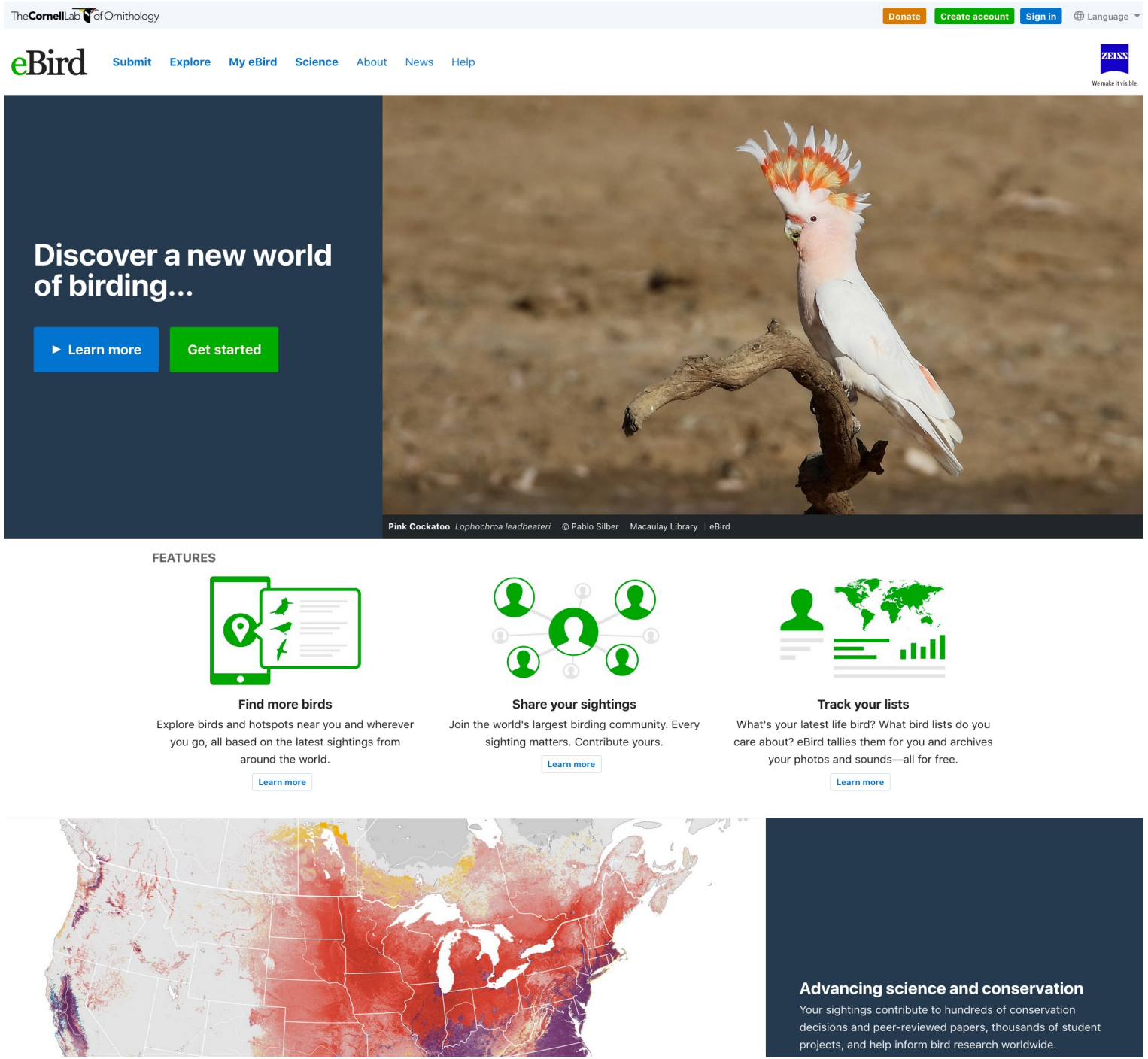
Freq. of frozen ground without snow *= # of frozen ground w/o snow days ÷ total # frozen days*

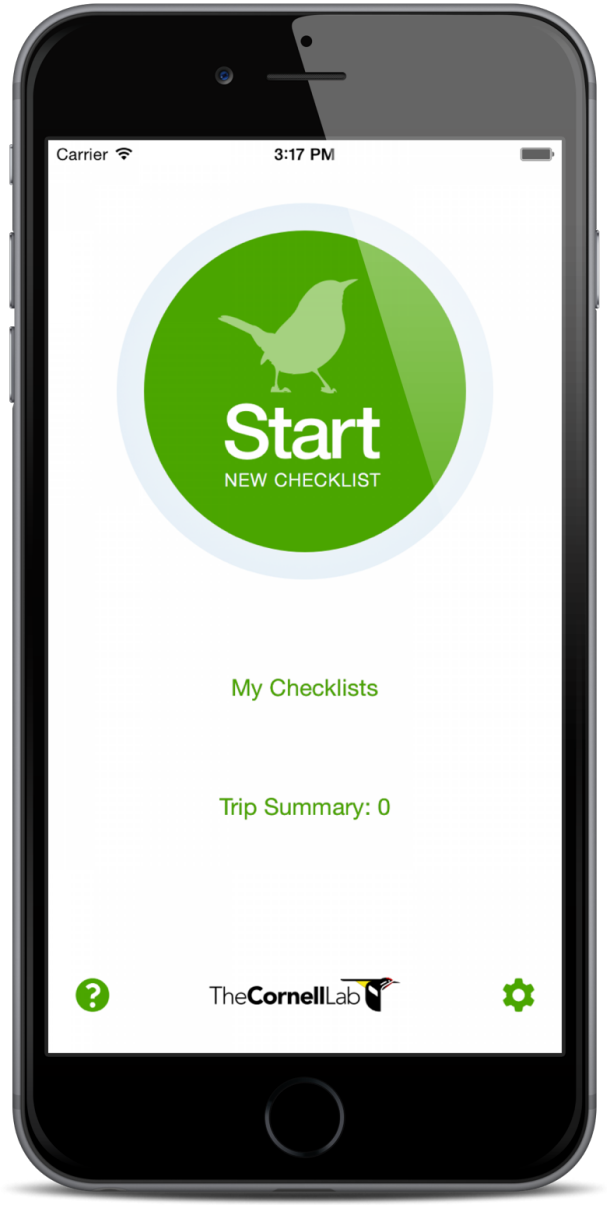



Winter Habitat Index
Snow Cover Variability
Snow Season Length
Frozen Ground Without Snow

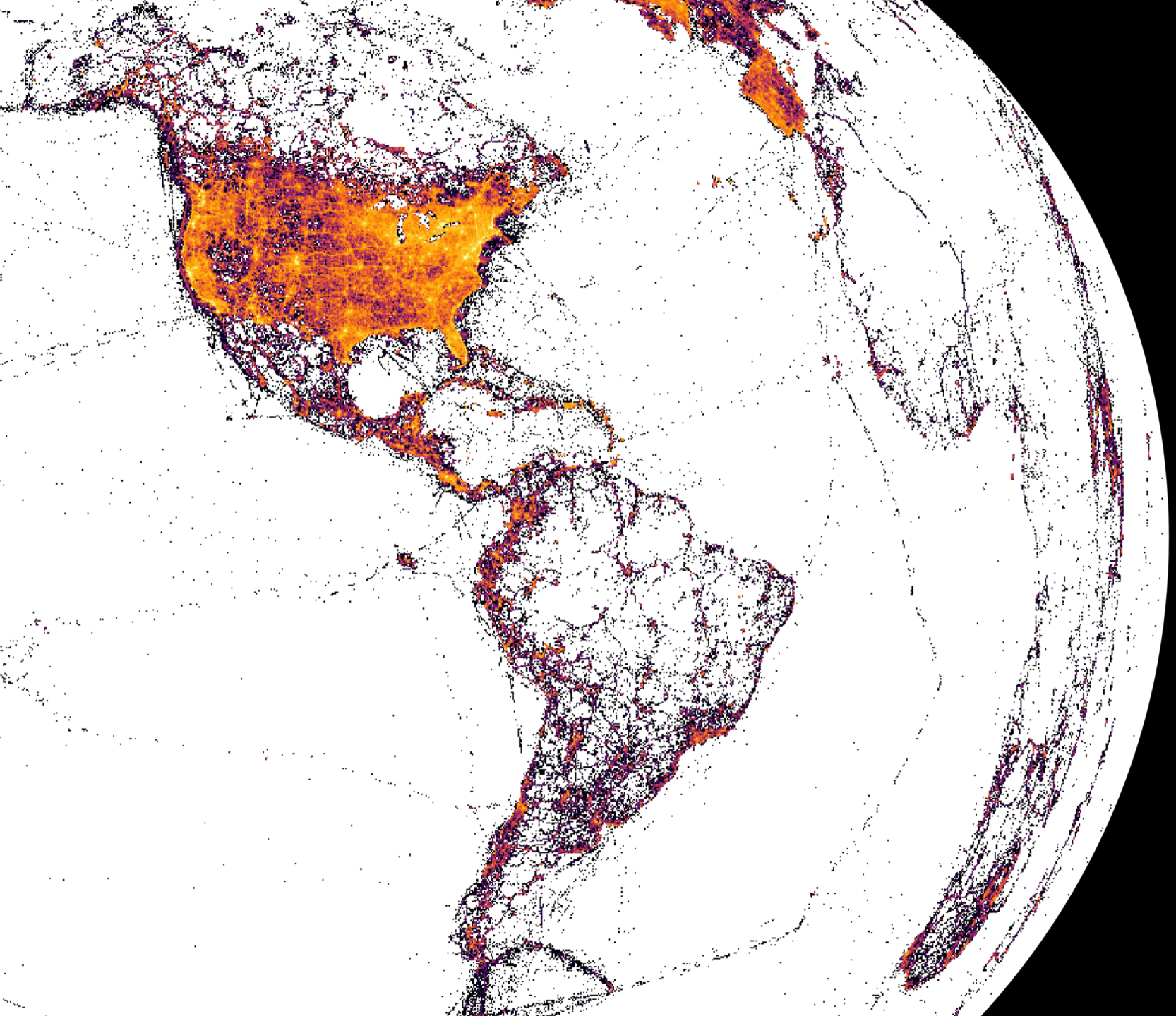
Winter Vertebrate Data Sources

Data Source	Occurrence/ Abundance	Spatial Extent/Resolution	Temporal Extent/Resolution	Taxa Included
eBird	☑ ☑	Global/3 km neighborhoods	2003-2020/Weekly	
Furbearer Harvest Database	☑ ☑	U.S. Wide/Varying Spatial Units	1900-2020/Annual	
IUCN Range Maps	☑ ✕	Global/~110 km	NA	





Sullivan et al. 2014 Biological Conservation

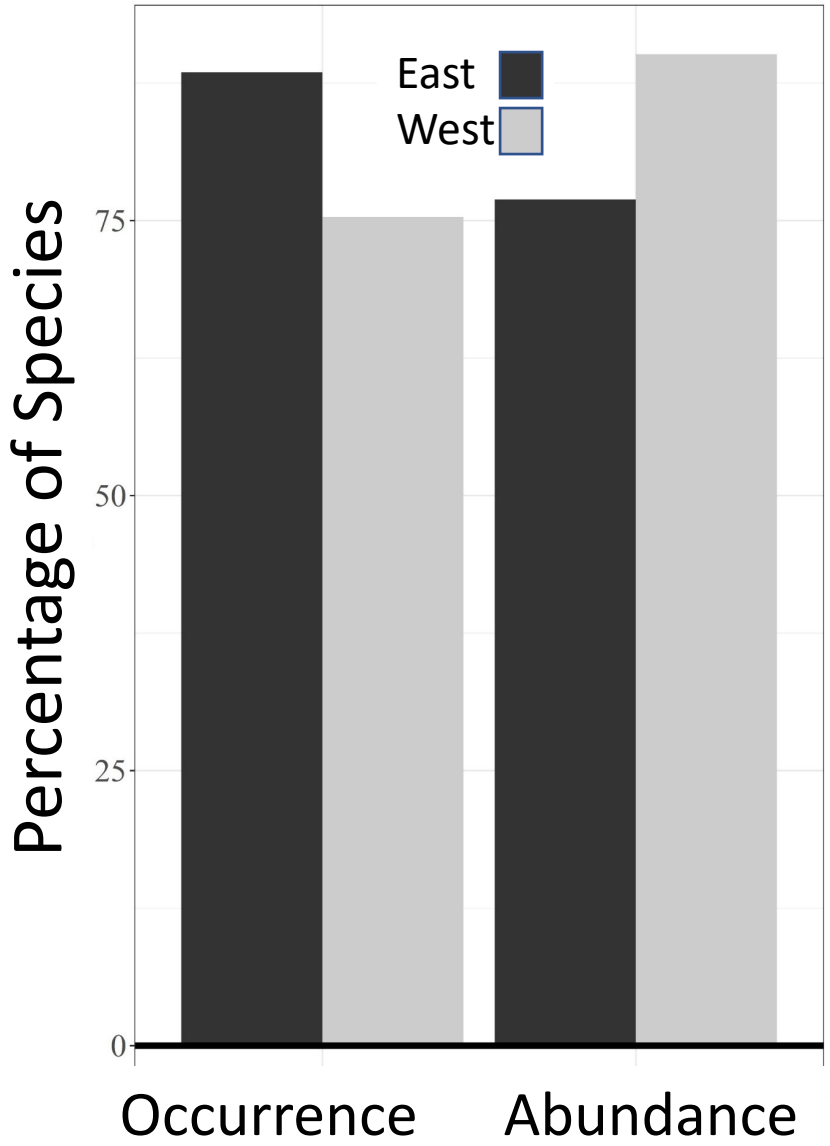


eBird

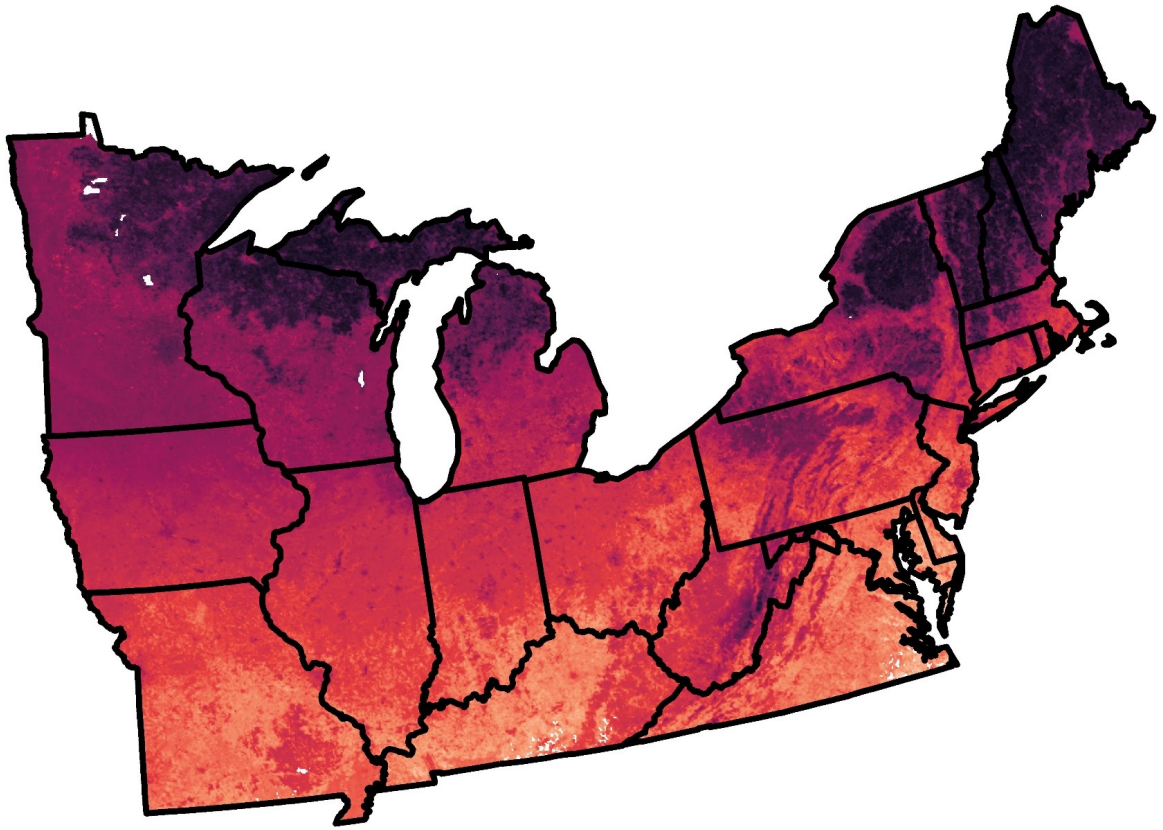
2004 – 2020
26M Checklists
6.5M Locations

Range
Occurrence
Abundance
Habitat

Snow cover as a biogeographic constraint



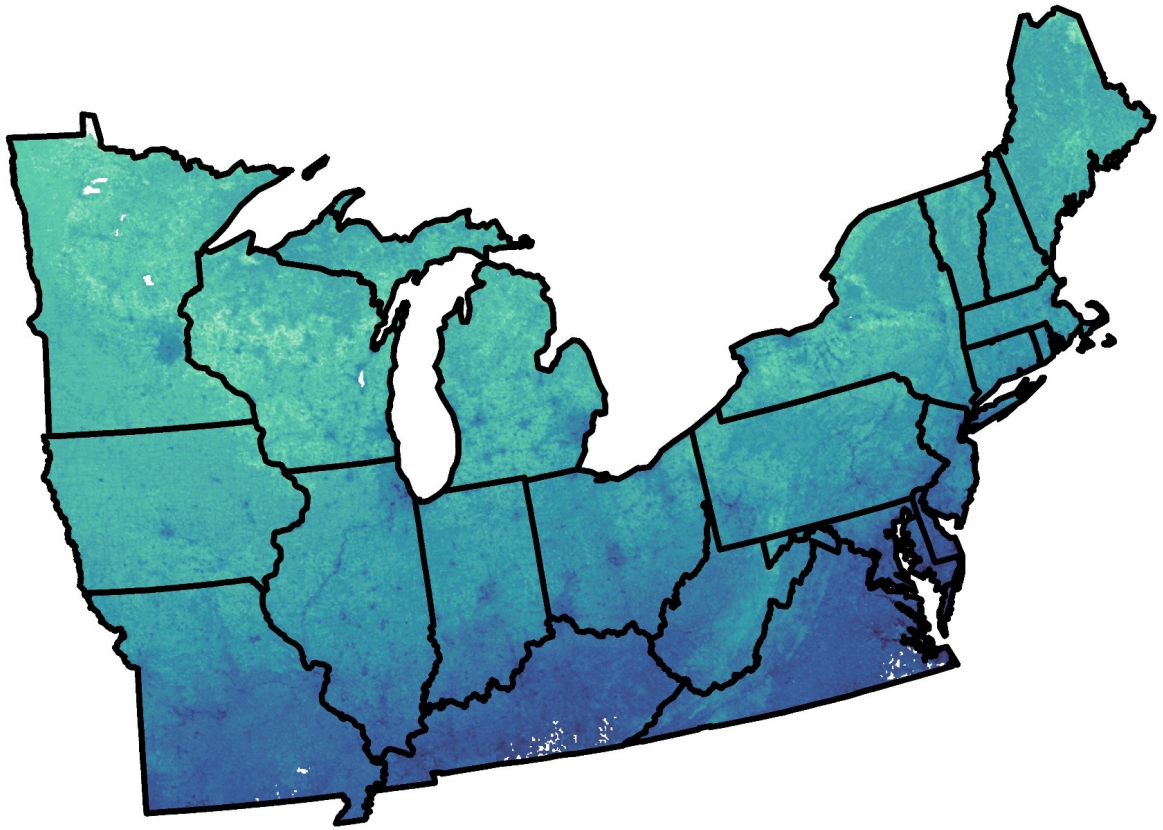
Winter Bird Species Richness



# of Species

15 20 25 30 35

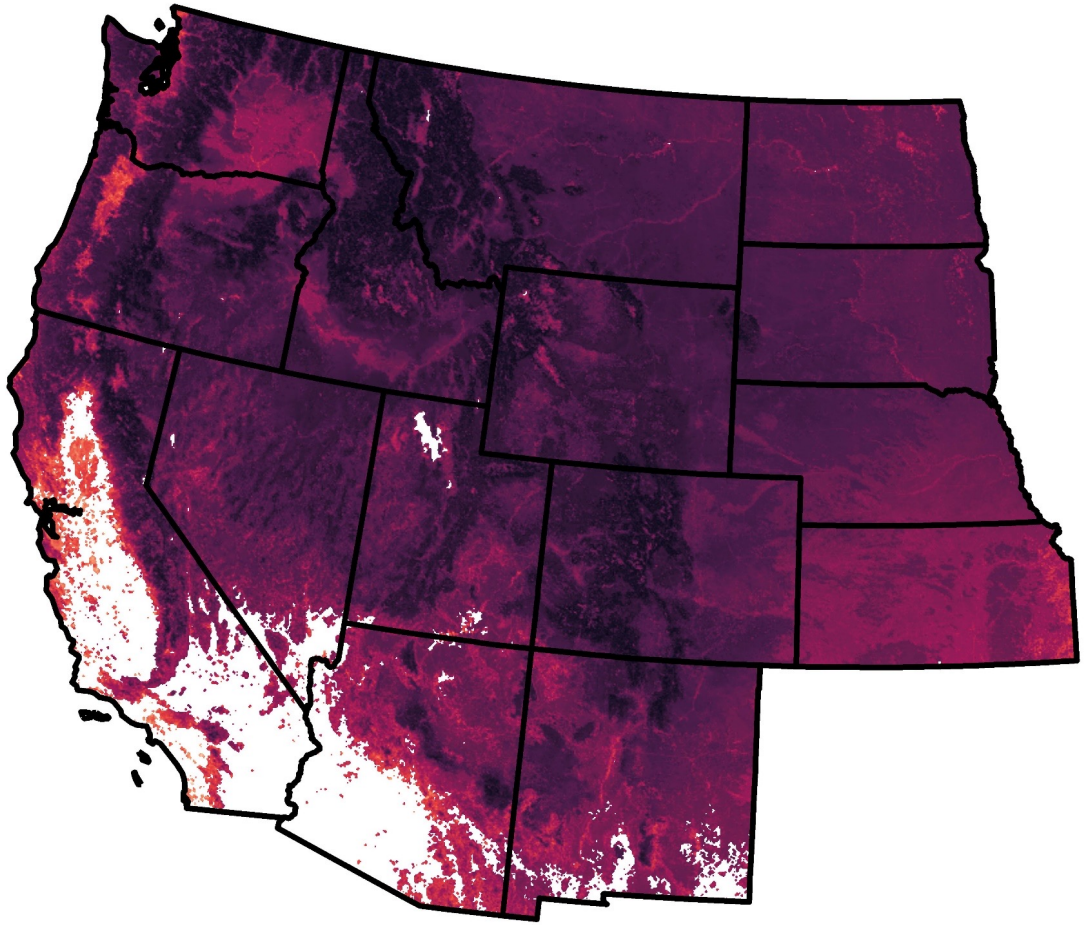
Snow-associated Species

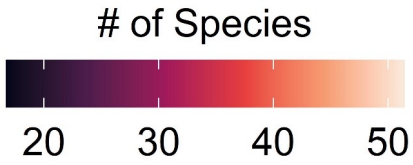


# of Species

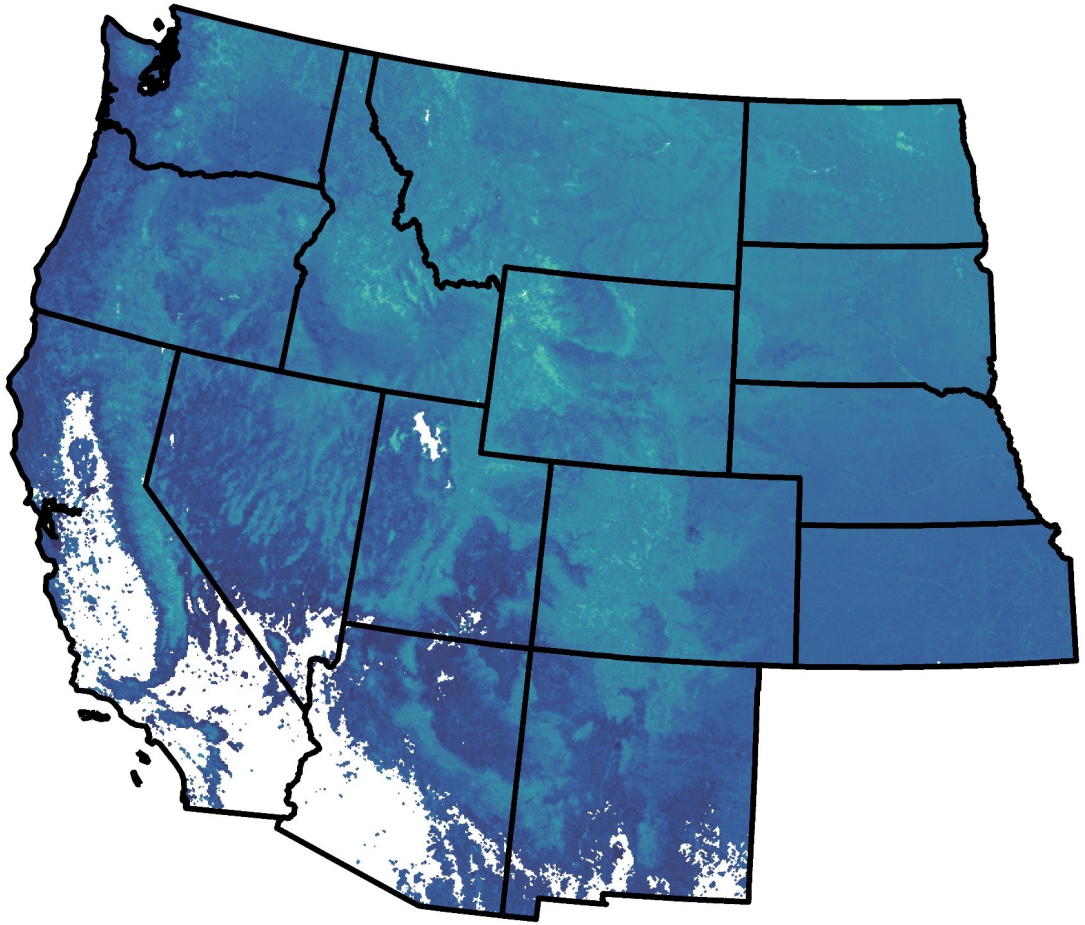
4 5 6 7 8

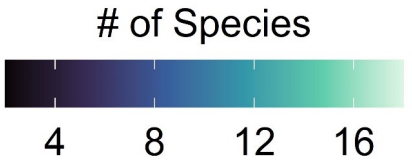
Winter Bird Species Richness





Snow-associated Species

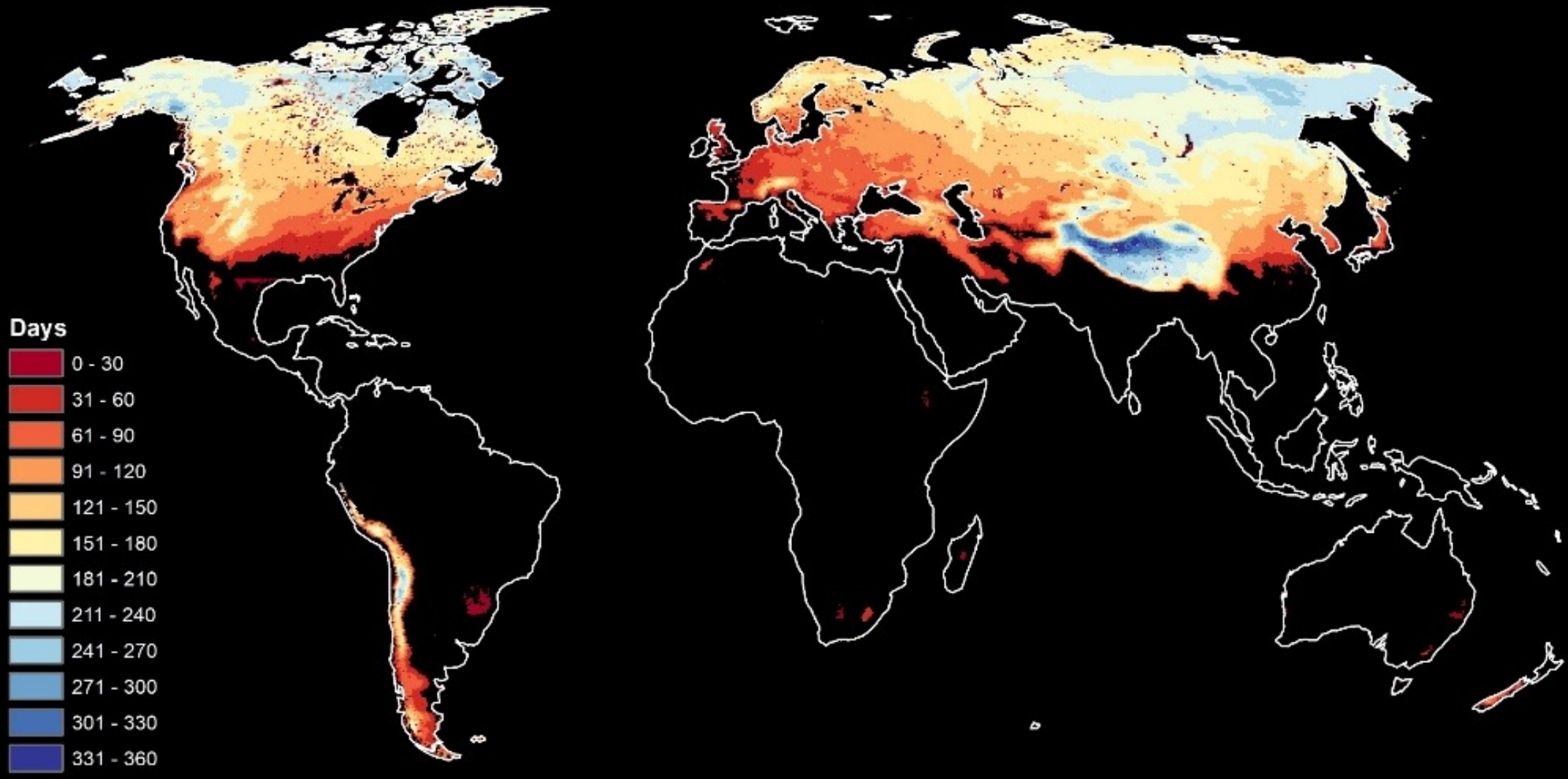




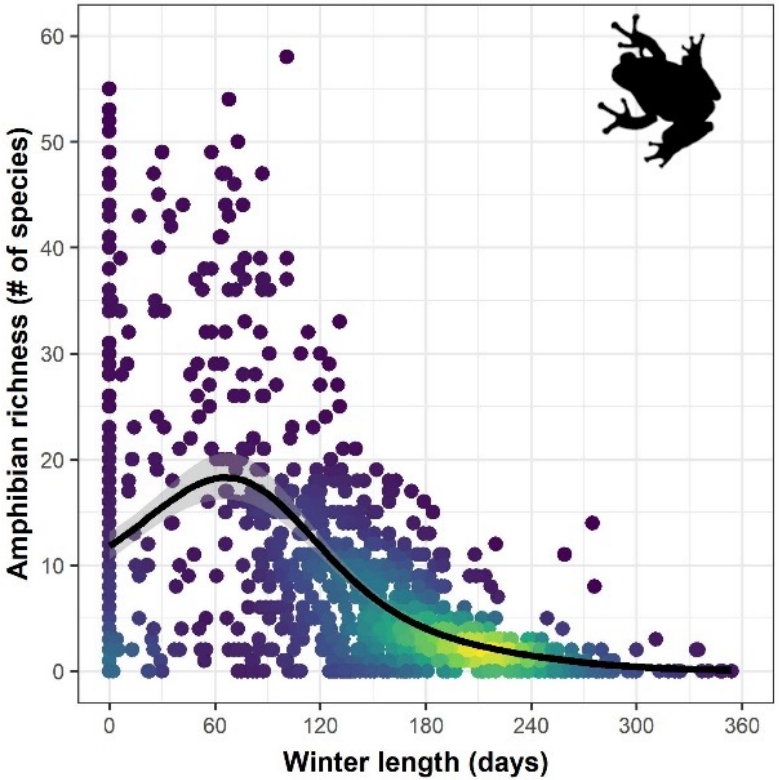
Winter Vertebrate Data Sources

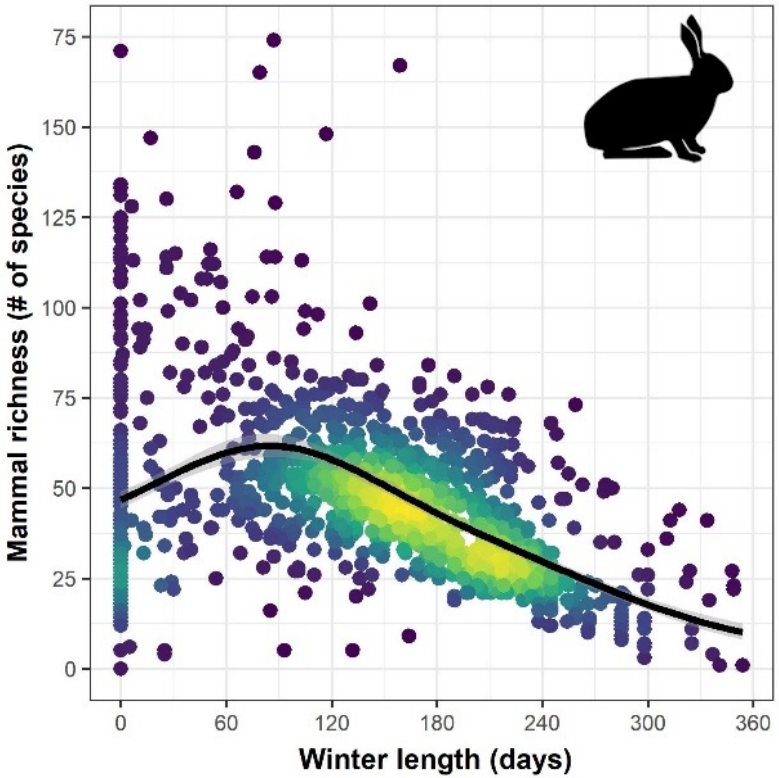
Data Source	Occurrence/ Abundance	Spatial Extent/Resolution	Temporal Extent/Resolution	Taxa Included
eBird	☑ ☑	Global/3 km neighborhoods	2003-2020/Weekly	
Furbearer Harvest Database	☑ ☑	U.S. Wide/Varying Spatial Units	1900-2020/Annual	
IUCN Range Maps	☑ ✕	Global/~110 km	NA	

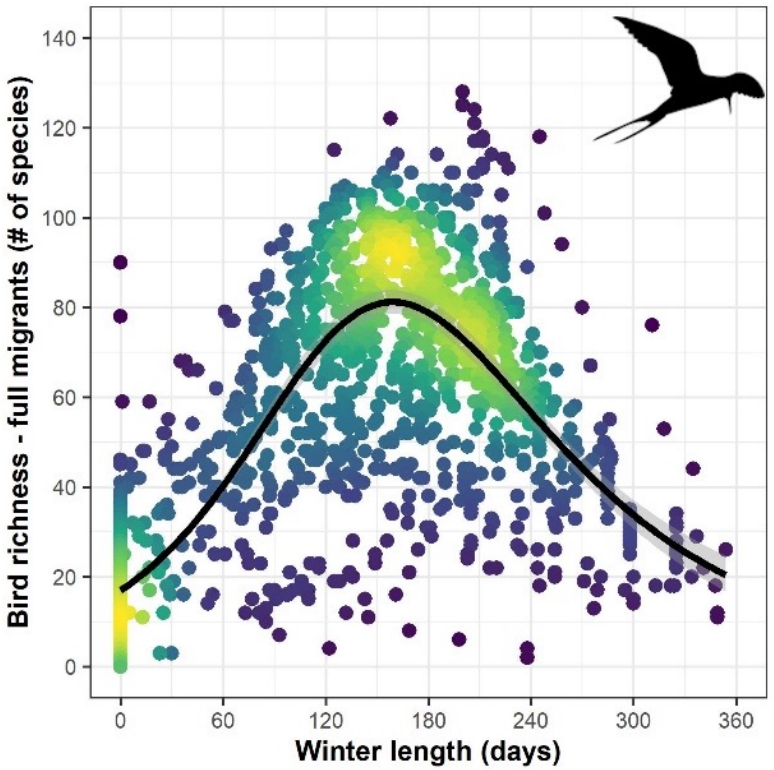
Global Winter Habitat Indices



Winter climate is a strong determinant of extratropical diversity gradients







Gudex-Cross et al. *In Review*

Conserving Winter Habitat

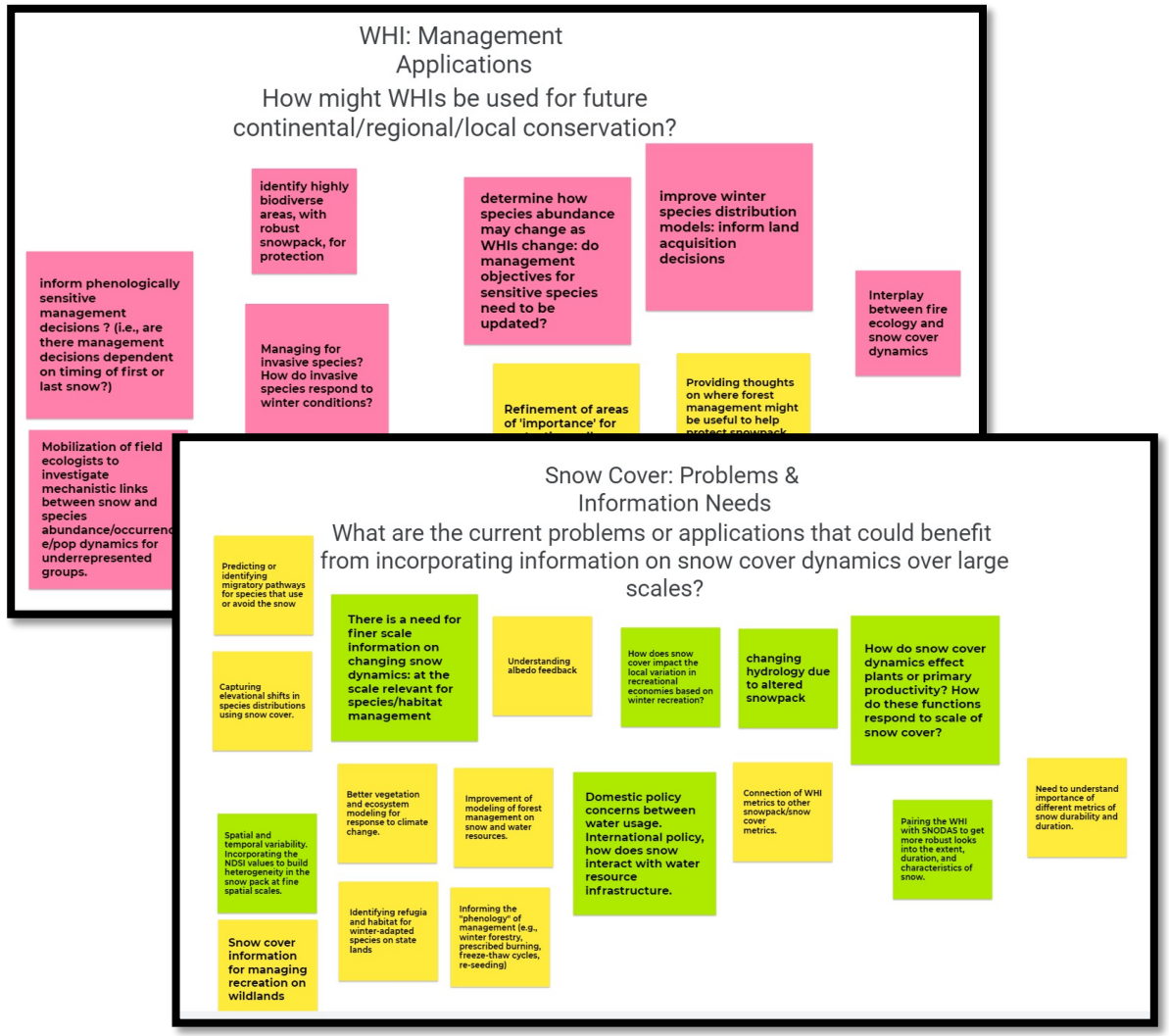
NATIONAL PARK SERVICE

The Nature Conservancy
Protecting nature. Preserving life.

USGS
science for a changing world

Washington Department of FISH and WILDLIFE

WISCONSIN DEPT. OF NATURAL RESOURCES

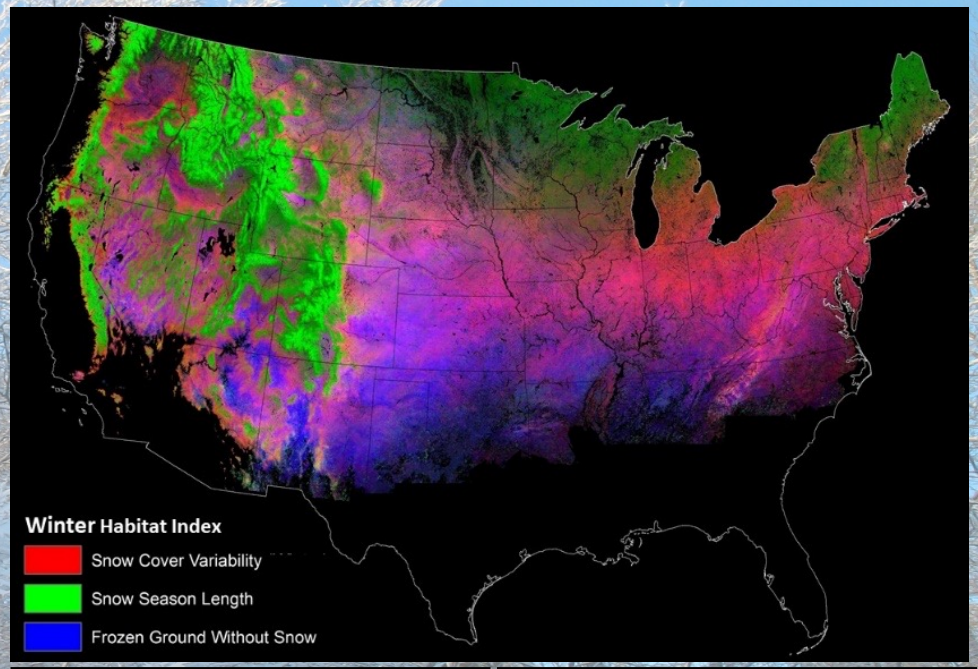


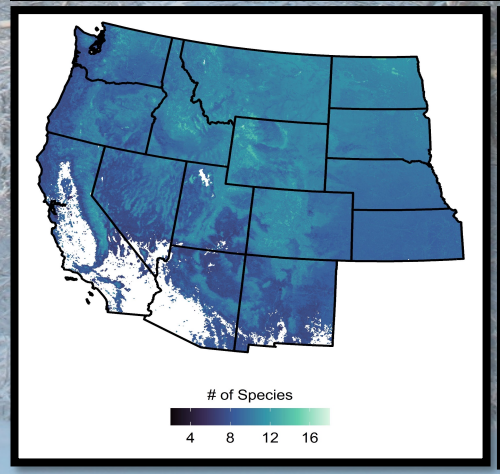
Future Steps

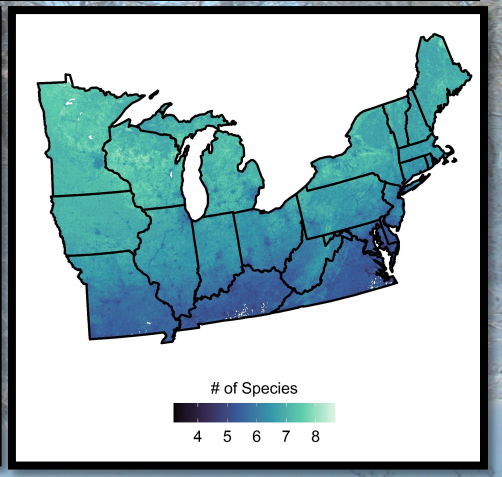
Mammals are next

Protected area analysis

Winter biodiversity conservation







silvis.forest.wisc.edu/maps-data/

UNIVERSITY of WISCONSIN–MADISON

SILVIS LAB
Spatial Analysis For Conservation and Sustainability

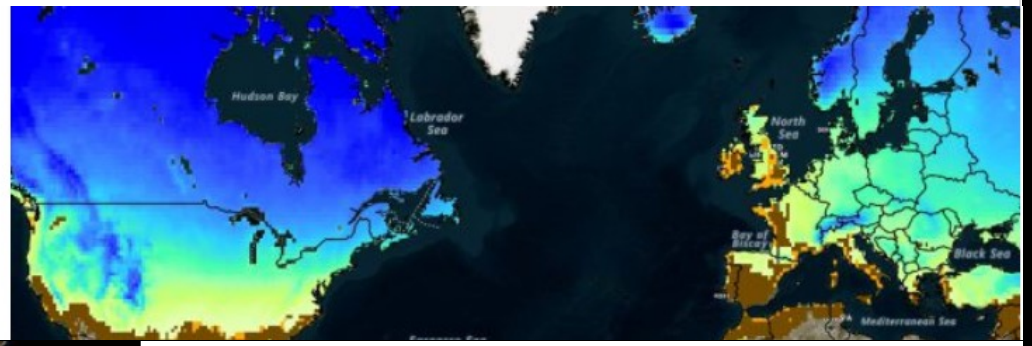
HOME | PEOPLE | RESEARCH | PUBLICATIONS | MAPS & DATA | ABOUT US | SIGN IN

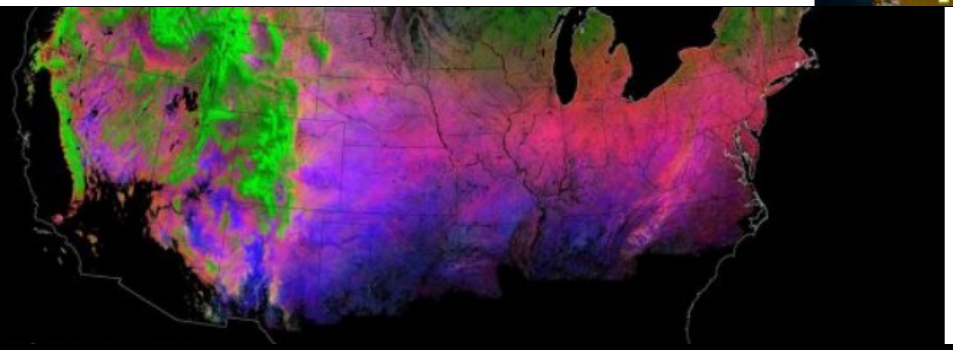
GLOBAL SUBNIVIUM DATA

Snow Cover & Snow Free Duration

Start/End/Length of Frozen Season

Global Subnivium Data »





WINTER HABITAT INDICES (WHIS)

WHIs based on Snow Cover Variability, Snow Season Length, and Frozen Ground without Snow duration.

WHIs Data & Maps »